Comparison of Functional Outcomes Following Bridge Synostosis with Non-Bone-Bridging Transtibial Combat-Related Amputations

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Background: The prevalence of penetrating wartime trauma to the extremities has increased in recent military conflicts. Substantial controversy remains in the orthopaedic and prosthetic literature regarding which surgical technique should be performed to obtain the most functional transtibial amputation. We compared self-reported functional outcomes associated with two surgical techniques for transtibial amputation: bridge synostosis (modified Ertl) and non-bone-bridging (modified Burgess).

Methods: A review of the prospective military amputee database was performed to identify patients who had undergone transtibial amputation between June 2003 and December 2010 at three military institutions receiving the majority of casualties from the most recent military conflicts; two of those institutions, Walter Reed Army Medical Center and National Naval Medical Center, have since been consolidated. Short Form-36, Prosthesis Evaluation Questionnaire, and functional data questions were completed by twenty-seven modified Ertl and thirty-eight modified Burgess isolated transtibial amputees.

Results: The average duration of follow-up after amputation (and standard deviation) was 32 ± 22.7 months, which was similar between groups. Residual limb length was significantly longer in the modified Ertl cohort by 2.5 cm ($p < 0.005$), and significantly more modified Ertl patients had delayed amputations ($p < 0.005$). There were no significant differences between groups with regard to any of the Short Form-36 domains or Prosthesis Evaluation Questionnaire subsections.

Conclusions: The modified Ertl and Burgess techniques offer similar functional outcomes in the young, active-duty military population managed with transtibial amputation.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Severe lower-extremity injuries remain frequent as a result of penetrating wartime trauma sustained in combat, often resulting in traumatic or surgical amputation. Substantial controversy remains in the orthopaedic and prosthetic literature regarding which surgical technique should be used to obtain the most functional transtibial amputation[1-9]. To date, to

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TABLE I Patient Demographic Characteristics and Injury Data

	Modified Ertl (N = 27)	Modified Burgess (N = 38)	P Value*
Age† *(yr)*	30.4 ± 6.9	31.6 ± 7.3	0.63
Residual limb length† *(mm)*	164.5 ± 25	139.6 ± 28.1	<0.005
Follow-up after amputation† *(mo)*	31.7 ± 22.1	31.7 ± 23.3	0.35
Delayed amputation‡ (more than twelve weeks from injury)	18 (67%)	3 (8%)	<0.005
Mechanism of injury‡			0.89
Improvised explosive device	14 (52%)	21 (55%)	
Other explosive blast	7 (26%)	11 (29%)	
Gunshot wound	3 (11%)	3 (8%)	
Motor vehicle collision or other blunt impact	3 (11%)	3 (8%)	

*Significance was set at p < 0.05. †The values are given as the mean and the standard deviation. ‡The values are given as the number of patients, with the percentage in parentheses.

our knowledge, there has been no adequate guidance in the available literature to definitively support performing one particular method[10-13]. The purpose of this study was to evaluate and compare the functional outcomes in two types of unilateral transtibial amputees, those with a bridge synostosis (modified Ertl procedure) and those without (modified Burgess procedure), as assessed by two validated outcome measures, the Prosthesis Evaluation Questionnaire (PEQ)[14] and Short Form-36 (SF-36)[15].

Materials and Methods

Following approval from our institutional review boards, we reviewed the prospective military amputee database to identify patients who had undergone transtibial amputations for combat-related injuries between June 2003 and December 2010 at our institutions; of the three original institutions, two (Walter Reed Medical Center and National Naval Medical Center) have since been consolidated. Inclusion criteria were isolated transtibial amputations without severe injury (defined as an abbreviated injury score ≥3 points) to the contralateral or proximal ipsilateral extremity, spine or pelvis, no severe traumatic brain injury, and no more than mild heterotopic ossification in the injured limb[16]. Of a total of 441 potential candidates with unilateral transtibial amputations who were identified from the amputee database, 155 met preliminary study inclusion criteria. We attempted to locate and contact these patients to match them on the basis of age and mechanism of injury at a 1:1 ratio between the two treatment cohorts, those with modified Ertl transtibial amputations and those with modified Burgess transtibial amputations.

Patients were contacted by phone or mail, were asked to provide consent for study participation, and were asked to complete the SF-36[15] and PEQ[14], as well as three brief questions regarding running activity, walking, and prosthesis wear endurance. Ultimately, seventy-nine patients could not be located or reached, eleven declined to participate, and sixty-five completed the requested questionnaires. Once the process of informed consent was complete, patient medical records were retrospectively reviewed for data regarding age, sex, mechanism of injury, associated injuries, and timing of amputation. Operative techniques for both types of amputation are relatively consistent among surgeons at our institutions, with only minor differences. The indications for the bridge synostosis were clinical or radiographic evidence of tibiofibular instability for a minority of patients, and were determined by surgeon and/or patient preference for the majority[17]. Our preferred techniques for performing both modified Ertl and modified Burgess transtibial amputations have been previously described[17,18].

Statistical Analysis

Statistical analysis was performed with JMP 9 statistical software (SAS, Cary, North Carolina). Descriptive statistics were used for all data. Frequency data for patient demographic characteristics (e.g., mechanism of injury and amputation timing) were analyzed with use of Fisher exact or chi-square analysis, as appropriate. Means of continuous variables were compared with use of the Wilcoxon signed-rank test for most data, which demonstrated skewed distributions, and the Student t test for those data that were normally distributed. Residual limb length, treated as a continuous variable, was compared with individual domains of the SF-36 and PEQ with use of the standard least-squares regression analysis. Significance was set at $\alpha \leq 0.05$, and all p values presented are two-tailed. Analysis of covariates (ANCOVA) was also performed, adjusting for propensity score. An a priori power analysis demonstrated that, to detect a fifteen-point difference in the mean PEQ and SF-36 scores between groups at a significance level of 0.05 and 80% power and assuming 20% standard deviation within groups, a sample size of twenty-eight subjects per group would be needed. Our null hypothesis was that there were no significant differences between the modified Ertl and Burgess groups.

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Results

Of 155 possible study participants, sixty-five returned the outcome questionnaires, reflecting a 42% response rate in this patient population. Because of the difficulty in locating many candidate patients and obtaining consent from only a few, as well as the irregular timing with which surveys were returned, the planned 1:1 ratio between treatment cohorts could not be precisely maintained, resulting in twenty-seven patients in the modified Ertl cohort and thirty-eight patients in the modified Burgess cohort. All enrolled subjects were male. Patient ages and mechanisms of injury were similar between cohorts. The mean duration following amputation (and standard deviation) was 32 ± 22.7 months, which was also similar between groups (Table I). Residual limb length was significantly longer in the modified Ertl

TABLE II SF-36, PEQ, and Functional Outcome Data for Modified Ertl Compared with Modified Burgess Transtibial Amputations

	Modified Ertl* (N = 27)	Modified Burgess* (N = 38)	P Value†	Comparison After Adjusting for Propensity Score†	U.S. Population Norms*‡[15]
SF-36 *(points)*					
Physical Functioning	78.3 ± 20.3	78.4 ± 21.2	0.98	0.94	84.2 ± 23.3
Role Limitations: Physical Health	61.6 ± 42.8	69.6 ± 38.2	0.44	0.94	80.9 ± 34.0
Role Limitations: Emotional Problems	81.0 ± 34.5	70.3 ± 41.4	0.26	0.58	81.3 ± 33.0
Vitality	67.3 ± 17.9	63.6 ± 21.8	0.46	0.75	60.9 ± 20.9
Mental Health	79.3 ± 14.7	75.9 ± 17.6	0.41	0.84	74.7 ± 18.1
Social Functioning	84.5 ± 16.8	79.5 ± 21.4	0.30	0.49	83.3 ± 22.7
Bodily Pain	78.1 ± 17.8	74.2 ± 24.1	0.46	0.74	75.2 ± 23.7
General Health	75.1 ± 23.1	76.6 ± 19.6	0.78	0.58	71.9 ± 20.3
Physical Component Summary	47.0 ± 10.5	48.5 ± 8.8	0.56	0.72	50.0 ± 10.0
Mental Component Summary	53.2 ± 8.0	49.9 ± 11.5	0.18	0.33	50.0 ± 10.0
Prosthetics Evaluation Questionnaire *(points)*					
Ambulation	81.2 ± 15.0	79.9 ± 15.7	0.73	0.84	NA
Appearance	73.8 ± 22.6	79.1 ± 14.8	0.28	0.35	NA
Frustration	76.0 ± 22.4	65.6 ± 30.0	0.12	0.29	NA
Perceived Response	92.5 ± 16.7	86.5 ± 19.6	0.19	0.35	NA
Residual Limb Health	63.6 ± 19.6	61.1 ± 19.2	0.62	0.60	NA
Social Burden	86.4 ± 18.1	85.5 ± 17.2	0.84	0.83	NA
Sounds	59.9 ± 22.7	65.8 ± 25.4	0.33	0.47	NA
Utility	78.0 ± 10.0	73.9 ± 17.6	0.24	0.50	NA
Well Being	86.5 ± 17.1	83.3 ± 19.3	0.47	0.28	NA
Functional					
How many miles do you currently run on a weekly basis? *(mi)*	5.0 ± 6.5	3.4 ± 5.6	0.30	0.56	NA
How many hours per day on average do you wear a prosthesis? *(hr)*	14.4 ± 2.6	13.8 ± 4.5	0.48	0.38	NA
How many consecutive hours can you walk in your prosthesis before you feel you need to stop and rest? *(hr)*	6.9 ± 6.15	8.5 ± 7.1	0.34	0.73	NA

*Values are given as the mean and the standard deviation. †Values are given as the probability. ‡NA = not available.

cohort by 24.9 mm ($p < 0.005$), and significantly more modified Ertl patients underwent delayed amputation ($p < 0.005$), defined as amputation more than twelve weeks after injury.

There were no significant differences between treatment cohorts with regard to any of the functional or health-related quality-of-life outcome variables assessed (Table II). We observed no floor effect (>20% of responses are the lowest possible value) or ceiling effect (>20% of responses are the highest possible value) for any domain of the SF-36 or subsection of the PEQ. There was a correlation between residual limb length in the modified Ertl cohort, treated as a continuous variable, and the frustration subsection of the PEQ ($p < 0.005$; adjusted R^2, 0.36) as well as the number of hours of prosthesis use per twenty-four-hour period ($p = 0.03$; adjusted R^2, 0.14). No significant associations of functional outcome with residual limb length were observed in the modified Burgess cohort.

Discussion

Functional outcomes following trauma-related lower-extremity amputation continue to be studied. The Lower Extremity Assessment Project (LEAP) study group examined functional outcomes following trauma-related lower-extremity amputation and subsequently reported longer-term follow-up of civilian patients who had undergone amputation compared with those who had undergone limb salvage[19,20]. They found that limb-salvage reconstruction for the treatment of injuries at or distal to the knee resulted in functional outcomes equivalent to those of amputation. Furthermore, regardless of the treatment option, long-term functional outcomes were often poor. Patient demographic characteristics that were significantly associated with worse outcomes included older age, female sex, nonwhite race, lower education level, living in a poor household, current or previous smoking habit, low self-efficacy (a subjective measure of one's own competence to complete tasks and reach goals), poor self-reported health status before the

injury, and involvement with the legal system in an effort to obtain disability payment[19,20]. Our patients were all active-duty military personnel at the time of injury, had been wounded in a war zone, and typically lacked most of the negative prognostic characteristics listed above.

It has also been well documented that even high-functioning trauma-related amputees continue to have perceived physical limitations and pain. Smith et al.[21] retrospectively reviewed seven years of transtibial amputees and found that the SF-36 Health Status Profile scores were significantly decreased from published normal age-matched scores in the categories of physical function and role limitations because of physical health problems and pain. Similarly, Gunawardena et al.[22] found that differences in profiles for traumatic war-injured soldiers with unilateral transtibial amputations compared with uninjured age matched controls were largest in scales sensitive to physical health. More proximal levels of amputation and problems with the residual limb and the uninjured leg were significantly associated with poor physical and mental health scores. It is unclear why our patients seem to compare more favorably with age-matched healthy controls, but our patients were all young and previously healthy and active prior to injury. Recent advances in prosthetic engineering may have also improved functional outcomes and patient comfort, although the LEAP study did not detect a correlation between functional outcome and technologically advanced prostheses[19]. Additionally, the robust interdisciplinary team approach to amputee management in the military system may result in achieving more successful outcomes.

Controversy remains in the orthopaedic and prosthetic literature regarding which surgical technique should be performed to obtain the best functional residual limb with transtibial amputations[1-9,23]. Most military surgeons utilize a long posterior gastrocnemius myocutaneous flap for soft-tissue closure when available, or flaps of opportunity if amputation is performed within the zone of injury[9]. With regard to the osseous reconstruction, some believe that the bridge synostosis method of amputation provides a sturdier and more functional end-bearing residual limb[6,12,13] compared with the more frequently performed transtibial amputation described by Burgess et al.[2]. Anecdotally, however, some patients and prosthetists report improved performance and prosthetic comfort with the bridge synostosis. Despite the relative paucity of evidence, some patients undergoing transtibial amputation have specifically requested a bridge synostosis procedure, and others with existing traditional amputations have requested revision, after learning of putative benefits of the amputation described by Ertl.

In 1949, von Ertl[6] wrote about an approach to transtibial and transfemoral amputation that had been used in the 1920s to manage injured Hungarian soldiers. Flexible bone graft and osteomyoplastic flaps were employed to ostensibly enhance prosthetic end-bearing and tolerability. The original surgical procedure consisted of using flexible cortico-periosteal flaps harvested after subcortico-periosteal resection of the osseous stumps to create a bridge of mature bone between the distal part of the tibia and the distal part of the fibula. von Ertl felt this procedure permitted a more end-bearing residual limb, likened to the heel of the foot. Moreover, he believed that the approximation of antagonistic muscles and sealing of the intramedullary canal afforded a more normal physiological state of the limb and helped prevent muscle atrophy. To date, to our knowledge, there has been no adequate guidance in the available literature to definitively support performing this method as opposed to the traditional Burgess amputation or another similar amputation.

J.W. Ertl et al.[24] reported at the American Academy of Orthopaedic Surgeons Annual Meeting in 1997 on 143 patients with 150 symptomatic transtibial amputations that underwent revision to a bridge synostosis. The primary amputations were performed as a result of trauma in 63%, vascular disease in 28%, infection in 7%, and tumor in 2% of cases. Over 92% reported a good or excellent outcome. Similarly, Deffer et al.[10] reported a five-year follow-up in 155 soldiers with the bone-bridge synostosis. Most patients required a revision after open guillotine amputation. Thirty-eight patients underwent autologous bone graft. Fifteen patients developed postoperative infection but only four patients developed a compromised formation of the terminal synostosis. All amputated patients achieved prosthesis usage.

Dougherty[11] reported a twenty-eight-year follow-up on seventy-two posttraumatic Vietnam War veterans who underwent amputation. Isolated transtibial amputees and transtibial amputees with additional injury were assessed subjectively to ascertain overall well-being and family situation and were also asked to complete the SF-36. There was an increased need for psychological care and more substantial long-term consequences for patients with additional injuries. Forty-two bone-bridge synostosis amputees were also compared with thirty traditional transtibial amputees. No significant differences were found between the two groups. Pinto and Harris[12] reported the results of their clinical experience with fifteen patients, five of whom underwent revision amputations. All patients produced a solid synostosis clinically within eight to ten weeks and were rehabilitated with use of a prosthesis. Complications included a fibula bone-bridge dislocation due to a fall on postoperative day 2, which required revision. Additionally, a wound dehiscence in a patient with diabetes required six months of local wound care to heal. Pinzur et al.[13] compared thirty-two patients of multiple ages with multiple diagnoses who had bone-bridging of the distal tibia and fibula at the time of transtibial amputation with those of a selected group of seventeen highly functional traditional transtibial amputees and found that the bone-bridging group had scores on the PEQ that were better than or comparable with those of the high-functioning traditional amputee group. The authors suggest that bone-bridging at the time of transtibial amputation may enhance patient perceived functional outcomes. However, these results were not reproduced when Pinzur and coauthors[25] more recently compared these findings with a small cohort of eight American amputees who had undergone modified Ertl procedures. Finally, Taylor et al.[26] recently

reported improved sickness impact profile scores among twenty-six patients with modified Ertl amputations compared with ten patients with traditional transtibial amputations. However, the study was limited by substantial reported differences in patient selection, surgical indications, and comorbidities, as well as differing postoperative protocols and durations of follow-up.

Our results most closely mirror those obtained by Dougherty[11] and the most recent publication by Pinzur et al.[25] on this topic, utilizing data obtained from the SF-36 and PEQ, and are strengthened modestly by our three functional questions. We were unable to demonstrate an appreciable difference in functional outcomes between the two cohorts in any measured outcome variable. We observed no benefit for the bridge-synostosis group, despite having a longer residual limb and being more frequently performed in the somewhat elective setting of a late amputation.

When planning which type of procedure to perform, several additional factors must be considered. Gwinn et al.[27] found that the bone-bridge transtibial amputation technique requires more surgical and tourniquet time because of additional intraoperative surgical steps being performed. However, both amputation techniques have comparable rates of short-term wound complications and associated blood loss. Additionally, amputation closure performed within the zone of injury is a significant predictor of subsequent wound problems regardless of the amputation technique used. Tintle and coauthors[17] reported that reoperations were needed at a significantly greater rate overall and for noninfectious complications following bone-bridge synostosis compared with modified Burgess transtibial amputations. Additionally, despite the putative positive selection bias favoring the bridge synostosis cohort, infection rates were not lower in that group. Finally, given the concern for the potential confounding effect of this selection bias on the results, we performed a propensity score analysis in an attempt to control for the nonrandom selection of patients to either the modified Ertl group or the modified Burgess group. After adjusting for propensity score[28], we still observed no demonstrable difference between groups.

We recognize the limitations of the current study. The number of subjects was limited and the number of candidate subjects who could not be reached or chose not to respond was relatively high, which may affect our ability to reject the null hypothesis. As such, the study may be underpowered to detect a small or even modest difference in the outcome measures used. We believe that this potential limitation is directly related to the low response rate observed. Alternatively, it is also possible that our outcome measures may not be sensitive enough to discern a difference between the two groups. Perhaps an array of high-demand physical tasks performed in a controlled gait laboratory or similar environment allowing the amputees to effectively test the limits of the residual limbs might demonstrate a difference between these two treatment groups. Nevertheless, these cohorts represent a carefully selected combat-wounded patient population with isolated single-extremity trauma.

In conclusion, health-related quality-of-life and prosthesis-specific outcomes are similar among male military patients undergoing either a modified Ertl transtibial amputation or a modified Burgess transtibial amputation, and appear to be independent of these surgical techniques. Any benefit in terms of quality of life or prosthetic-specific function associated with the bridge synostosis procedure could not be demonstrated by this study. Given these findings, coupled with the additional associated risks of increased surgical time and complications noted in previous investigations, we do not recommend the routine performance of the bridge-synostosis transtibial amputation technique in this patient population. Prospective randomized trials with more sensitive outcome measures are needed to better define which patients, if any, for whom the bridge-synostosis procedure may be most beneficial. ■

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References

1. Bach S, Noreng MF, Tjéllden NU. Phantom limb pain in amputees during the first 12 months following limb amputation, after preoperative lumbar epidural blockade. Pain. 1988 Jun;33(3):297-301.

2. Burgess EM, Romano RL, Zettl JH, Schrock RDJ Jr. Amputations of the leg for peripheral vascular insufficiency. J Bone Joint Surg Am. 1971 Jul;53(5):874-90.

3. Burgess EM, Matsen FA 3rd. Determining amputation levels in peripheral vascular disease. J Bone Joint Surg Am. 1981 Dec;63(9):1493-7.

4. Dickhaut SC, DeLee JC, Page CP. Nutritional status: importance in predicting wound-healing after amputation. J Bone Joint Surg Am. 1984 Jan;66(1):71-5.

5. Dillingham TR, Pezzin LE, MacKenzie EJ. Limb amputation and limb deficiency: epidemiology and recent trends in the United States. South Med J. 2002 Aug;95(8):875-83.

6. Ertl J. Uber amputationsstumpfe. Chirurg. 1949;20:218-24. German.

7. Fitzpatrick MC. The psychologic assessment and psychosocial recovery of the patient with an amputation. Clin Orthop Relat Res. 1999 Apr;(361):98-107.

8. Honkamp N, Amendola A, Hurwitz S, Saltzman CL. Retrospective review of eighteen patients who underwent transtibial amputation for intractable pain. J Bone Joint Surg Am. 2001 Oct;83(10):1479-83.

9. Smith DG, Fergason JR. Transtibial amputations. Clin Orthop Relat Res. 1999 Apr;(361):108-15.

10. The American Academy of Orthopaedic Surgeons. J Bone Joint Surg Am. 1971 Jul 01;53(5):1017-33.

11. Dougherty PJ. Transtibial amputees from the Vietnam War. Twenty-eight-year follow-up. J Bone Joint Surg Am. 2001 Mar;83(3):383-9.

12. Pinto MA, Harris WW. Fibular segment bone bridging in trans-tibial amputation. Prosthet Orthot Int. 2004 Dec;28(3):220-4.

13. Pinzur MS, Pinto MA, Saltzman M, Batista F, Gottschalk F, Juknelis D. Health-related quality of life in patients with transtibial amputation and reconstruction with bone bridging of the distal tibia and fibula. Foot Ankle Int. 2006 Nov;27(11):907-12.

14. Legro MW, Reiber GD, Smith DG, del Aguila M, Larsen J, Boone D. Prosthesis evaluation questionnaire for persons with lower limb amputations: assessing prosthesis-related quality of life. Arch Phys Med Rehabil. 1998 Aug;79(8):931-8.

15. Ware JE. SF-36 health status questionnaire. Boston, MA: Institute for the Improvement of Medical Care and Health, New England Medical Center Hospital, Quality Quest, Inc., 1989.

16. Potter BK, Burns TC, Lacap AP, Granville RR, Gajewski DA. Heterotopic ossification following traumatic and combat-related amputations. Prevalence, risk factors, and preliminary results of excision. J Bone Joint Surg Am. 2007 Mar;89(3):476-86.

17. Tintle SM, Keeling JJ, Forsberg JA, Shawen SB, Andersen RC, Potter BK. Operative complications of combat-related transtibial amputations: a comparison of the modified burgess and modified Ertl tibiofibular synostosis techniques. J Bone Joint Surg Am. 2011 Jun 1;93(11):1016-21.

18. Keeling JJ, Schon LC. Tibiofibular bridge synostosis in below-knee amputation. Tech Foot Ankle Surg. 2007;6(3):156-61.

19. MacKenzie EJ, Bosse MJ, Castillo RC, Smith DG, Webb LX, Kellam JF, Burgess AR, Swiontkowski MF, Sanders RW, Jones AL, McAndrew MP, Patterson BM, Travison TG, McCarthy ML. Functional outcomes following trauma-related lower-extremity amputation. J Bone Joint Surg Am. 2004 Aug;86(8):1636-45.

20. MacKenzie EJ, Bosse MJ, Pollak AN, Webb LX, Swiontkowski MF, Kellam JF, Smith DG, Sanders RW, Jones AL, Starr AJ, McAndrew MP, Patterson BM, Burgess AR, Castillo RC. Long-term persistence of disability following severe lower-limb trauma. Results of a seven-year follow-up. J Bone Joint Surg Am. 2005 Aug;87(8):1801-9.

21. Smith DG, Horn P, Malchow D, Boone DA, Reiber GE, Hansen STJ Jr. Prosthetic history, prosthetic charges, and functional outcome of the isolated, traumatic below-knee amputee. J Trauma. 1995 Jan;38(1):44-7.

22. Gunawardena NS, Seneviratne RdeA, Athauda T. Functional outcomes of unilateral lower limb amputee soldiers in two districts of Sri Lanka. Mil Med. 2006 Apr;171(4):283-7.

23. Burgess EM, Matsen FA 3rd, Wyss CR, Simmons CW. Segmental transcutaneous measurements of PO2 in patients requiring below-the-knee amputation for peripheral vascular insufficiency. J Bone Joint Surg Am. 1982 Mar;64(3):378-82.

24. Ertl JW, Ertl JJP, Ertl WJ, Stokosa JJ. The Ertl osteomyoplastic lower extremity amputation reconstruction: technique and long-term results. Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons; 1997 Feb 13-17; San Francisco, CA.

25. Pinzur MS, Beck J, Himes R, Callaci J. Distal tibiofibular bone-bridging in transtibial amputation. J Bone Joint Surg Am. 2008 Dec;90(12):2682-7.

26. Taylor BC, French B, Poka A, Blint A, Mehta S. Osteomyoplastic and traditional transtibial amputations in the trauma patient: perioperative comparisons and outcomes. Orthopedics. 2010 Jun;33(6):390.

27. Gwinn DE, Keeling J, Froehner JW, McGuigan FX, Andersen R. Perioperative differences between bone bridging and non-bone bridging transtibial amputations for wartime lower extremity trauma. Foot Ankle Int. 2008 Aug;29(8):787-93.

28. D'Agostino RB Jr. Propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group. Stat Med. 1998 Oct 15;17(19):2265-81.